CERTIFICATE OF ACCREDITATION

The ANSI National Accreditation Board

Hereby attests that

Rothe Enterprises, Inc. at
Metrology and Calibration Laboratory Services
(WMCLS) NASA / Wallops Flight Facility
34200 Fulton St., Building F-160
Wallops Island, VA 23337

Fulfills the requirements of

ISO/IEC 17025:2017

and national standards

ANSI/NCSL Z540-1-1994 (R2002) and
ANSI/NCSL Z540.3-2006 (R2013)

In the field of

CALIBRATION

This certificate is valid only when accompanied by a current scope of accreditation document.
The current scope of accreditation can be verified at www.anab.org.

Jason Stine, Vice President

Expiry Date: 21 May 2025

Certificate Number: AC-2986

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2017. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (refer to joint ISO-ILAC-IAF Communiqué dated April 2017).

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2017

AND

ANSI/NCSL Z540-1-1994 (R2002)
ANSI/NCSL Z540.3-2006 (R2013)

Rothe Enterprises, Inc. at
Metrology and Calibration Laboratory Services (WMCLS)
NASA / Wallops Flight Facility
34200 Fulton St., Building F-160
Wallops Island, VA 23337
Edward Woodring 757-824-2368

CALIBRATION

Valid to: **May 21, 2025** Certificate Number: **AC-2986**

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Voltage – Source [1]	(0 to 0.22) V (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1 100) V	9 µV/V + 0.8 µV 8 µV/V + 1.2 µV 8 µV/V + 4 µV 8 µV/V + 8 µV 9 µV/V + 100 µV 11 µV/V + 600 µV	Fluke 5700A Multifunction Calibrator with 5725A Amplifier
	Up to 330 mV 330 mV to 3.3 V (3.3 to 33) V (33 to 330) V 330 V to 1 kV	3 µV/V + 1 µV 2 µV/V + 1.5 µV 12 µV/V + 20 µV 18 µV/V + 150 µV 18 µV/V + 1.5 mV	Fluke 5522A Multi-Product Calibrator
DC Voltage – Measure [1]	(0 to 100) mV 100 mV to 1 V (1 to 10) V (10 to 100) V (100 to 1 000) V	9 µV/V + 300 nV 8 µV/V + 300 nV 8 µV/V + 500 nV 10 µV/V + 30 µV 22 µV/V + 100 µV	Hewlett Packard 3458A Digital Multimeter

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
DC Current – Source [1]	Up to 220 µA (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A (2.2 to 11) A	50 µA/A + 8 nA 50 µA/A + 8 nA 50 µA/A + 80 nA 60 µA/A + 0.8 µA 80 µA/A + 25 µA 360 µA/A + 480 µA	Fluke 5700A Multifunction Calibrator with 5725A Amplifier
DC Current – Source [1]	(0 to 330) µA 330 µA to 3.3 mA (3.3 to 33) mA (33 to 330) mA 330 mA to 1.1A (1.1 to 3.3) A (3.3 to 11) A (11 to 20.5) A	150 µA/A + 0.02 µA 100 µA/A + 0.05 µA 100 µA/A +0.25 µA 100 µA/A + 2.5 µA 200 µA/A + 40 µA 380 µA/A + 40 µA 500 µA/A + 500 µA 1 mA/A + 750 µA	Fluke 5522A Multi-Product Calibrator
DC Current – Measure [1]	(0 to 100) µA 100 µA to 1 mA (1 to 10) mA (10 to 100) mA 100 mA to 1 A	20 µA/A + 800 pA 20 µA/A +5 nA 20 µA/A + 50 nA 20 µA/A + 500 nA 110 µA/A + 10 µA	Hewlett Packard 3458A Digital Multimeter
	(0 A to 100) A	39 µA/A + 10 µA	Hewlett Packard 3458A Digital Multimeter with Current Shunts
AC Voltage – Source [1]	220 µV to 2.2 mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz (2.2 to 22) mV (10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	 550 µV/V + 4.5 µA 210 µV/V + 4.5 µV 105 µV/V + 4.5 µV 370 µV/V + 4.5 µV 850 µV/V + 7 µV 1.1 mV/V + 13 µV 1.7 mV/V + 25 µV 3.4 mV/V + 25 µV 500 µV/V + 5 µV 210 µV/V + 5 µV 105 µV/V + 5 µV 370 µV/V + 5 µV 850 µV/V + 7 µV 1.1 mV/V + 12 µV 1.7 mV/V + 25 µV 3.4 mV/V + 25 µV	Fluke 5700A Multifunction Calibrator with 5725A Amplifier

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source [1]	(22 to 220) mV		Fluke 5700A Multifunction Calibrator with 5725A Amplifier
	(10 to 20) Hz	550 µV/V + 13 µV	
	(20 to 40) Hz	210 µV/V + 8 µV	
	40 Hz to 20 kHz	105 µV/V + 8 µV	
	(20 to 50) kHz	320 µV/V + 8 µV	
	(50 to 100) kHz	850 µV/V + 25 µV	
	(100 to 300) kHz	1.1 mV/V + 25 µV	
	(300 to 500) kHz	1.7 mV/V + 35 µV	
	500 kHz to 1 MHz	3.4 mV/V + 80 µV	
	220 mV to 2.2 V		
	(10 to 20) Hz	500 µV/V + 80 µV	
	(20 to 40) Hz	160 µV/V + 25 µV	
	40 Hz to 20 kHz	75 µV/V + 6 µV	
	(20 to 50) kHz	120 µV/V + 16 µV	
	(50 to 100) kHz	250 µV/V + 70 µV	
	(100 to 300) kHz	500 µV/V + 130 µV	
	(300 to 500) kHz	1.3 mV/V + 350 µV	
	500kHz to 1 MHz	2.7 mV/V + 850 µV	
	(2.2 to 22) V		
	(10 to 20) Hz	500 µV/V + 800 µV	
	(20 to 40) Hz	160 µV/V + 250 µV	
	40 Hz to 20 kHz	75 µV/V + 60 µV	
	(20 to 50) kHz	120 µV/V + 160 µV	
	(50 to 100) kHz	250 µV/V + 350 µV	
	(100 to 300) kHz	500 µV/V + 1.5 mV	
	(300 to 500) kHz	1.3 mV/V + 4.3 mV	
	500 kHz to 1 MHz	2.7 mV/V + 8.5 mV	
	(22 to 220) V		
	(10 to 20) Hz	500 µV/V + 8 mV	
	(20 to 40) Hz	160 µV/V + 2.5 mV	
	40 Hz to 20 kHz	80 µV/V + 0.8 mV	
	(20 to 50) kHz	220 µV/V + 3.5 mV	
	(50 to 100) kHz	500 µV/V + 8 mV	
	(100 to 300) kHz	1.5 mV/V + 90 mV	
	(300 to 500) kHz	4.7 mV/V + 90 mV	
	500 kHz to 1 MHz	12 mV/V + 190 mV	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source [1]	(220 to 1 100) V		Fluke 5700A Multifunction Calibrator with 5725A Amplifier
	(15 to 50) Hz	400 µV/V + 16 mV
	50 Hz to 1 kHz	80 µV/V + 3.5 mV
	40 Hz to 1 kHz	90 µV/V + 4 mV
	(1 to 20) kHz	165 µV/V + 6 mV
	(20 to 30) kHz	600 µV/V + 11 mV
	(220 to 750) V	
	30 Hz to 50 kHz	600 µV/V + 11 mV
	(50 to 100) kHz	2.3 mV/V + 45 mV
AC Voltage – Source [1]	(1 to 33) mV		Fluke 5522A Multi-Product Calibrator
	(10 to 45) Hz	800 µV/V + 6 µV
	45 Hz to 10 kHz	150 µV/V + 6 µV
	(10 to 20) kHz	200 µV/V + 6 µV
	(20 to 50) kHz	1 mV/V + 6 µV
	(50 to 100) kHz	3.5 mV/V + 12 µV
	(100 to 500) kHz	8 mV/V + 50 µV
	(33 to 330) mV	
	(10 to 45) Hz	300 µV/V + 8 µV
	45 Hz to 10 kHz	145 µV/V + 8 µV
	(10 to 20) kHz	160 µV/V + 8 µV
	(20 to 50) kHz	350 µV/V + 8 µV
	(50 to 100) kHz	800 µV/V + 32 µV
	(100 to 500) kHz	2 mV/V + 70 µV
	(0.33 to 3.3) V	
	(10 to 45) Hz	300 µV/V + 50 µV
	45 Hz to 10 kHz	150 µV/V + 60 µV
	(10 to 20) kHz	190 µV/V + 60 µV
	(20 to 50) kHz	300 µV/V + 50 µV
	(50 to 100) kHz	700 µV/V + 125 µV
	(100 to 500) kHz	2.4 mV/V + 600 µV
	(3.3 to 33) V	
	(10 to 45) Hz	300 µV/V + 650 µV
	45 Hz to 10 kHz	150 µV/V + 600 µV
	(10 to 20) kHz	240 µV/V + 600 µV
	(20 to 50) kHz	350 µV/V + 600 µV
	(50 to 100) kHz	900 µV/V + 1.6 mV

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Source [1]	(33 to 330) V		Fluke 5522A Multi-Product Calibrator
	45Hz to 1 kHz	190 µV/V + 2 mV
	(1 to 10) kHz	200 µV/V + 6 mV
	(10 to 20) kHz	250 µV/V + 6 mV
	(20 to 50) kHz	300 µV/V + 6 mV
	(50 to 100) kHz	2 mV/V + 50 mV
	(330 to 1 020) V	
	45 Hz to 1 kHz	300 µV/V + 10 mV
	(1 to 5) kHz	250 µV/V + 10 mV
	(5 to 10) kHz	300 µV/V + 10 mV
AC Voltage – Measure [1]	Up to 10 mV		Hewlett Packard 3458A Digital Multimeter
	(1 to 40) Hz	300 µV/V + 3 µV
	40 Hz to 1 kHz	200 µV/V + 1.1 µV
	(1 to 20) kHz	300 µV/V + 1.1 µV
	(20 to 50) kHz	1 mV/V + 1.1 µV
	(50 to 100) kHz	5 mV/V + 1.1 µV
	(100 to 300) kHz	40 mV/V + 2 µV
	(10 to 100) mV	
	(1 to 40) Hz	70 µV/V + 4 µV
	40 Hz to 1 kHz	70 µV/V + 2 µV
	(1 to 20) kHz	140 µV/V + 2 µV
	(20 to 50) kHz	300 µV/V + 2 µV
	(50 to 100) kHz	800 µV/V + 2 µV
	(100 to 300) kHz	3 mV/V + 10 µV
	300 kHz to 1 MHz	10 mV/V + 10 µV
	(1 to 2) MHz	15 mV/V + 10 µV
	(0.1 to 1) V	
	(1 to 40) Hz	70 µV/V + 40 µV
	40 Hz to 1 kHz	70 µV/V + 20 µV
	(1 to 20) kHz	140 µV/V + 20 µV
	(20 to 50) kHz	300 µV/V + 20 µV
	(50 to 100) kHz	800 µV/V + 20 µV
	(100 to 300) kHz	3 mV/V + 100 µV
	300 kHz to 1 MHz	10 mV/V + 100 µV
	(1 to 2) MHz	15 mV/V + 100 µV

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure [1]	(1 to 10) V		Hewlett Packard 3458A Digital Multimeter
	(1 to 40) Hz	70 µV/V + 400 µV	
	40 Hz to 1 kHz	70 µV/V + 200 µV	
	(1 to 20) kHz	140 µV/V + 200 µV	
	(20 to 50) kHz	300 µV/V + 200 µV	
	(50 to 100) kHz	800 µV/V + 200 µV	
	(100 to 300) kHz	3 mV/V + 1 mV	
	300 kHz to 1 MHz	10 mV/V + 1 mV	
	(1 to 2) MHz	15 mV/V + 1 mV	
	(10 to 100) V		
	(1 to 40) Hz	200 µV/V + 4 mV	
	40 Hz to 1 kHz	200 µV/V + 2 mV	
	(1 to 20) kHz	200 µV/V + 2 mV	
	(20 to 50) kHz	350 µV/V + 2 mV	
	(50 to 100) kHz	1.2 mV/V + 2 mV	
	(100 to 300) kHz	4 mV/V + 10 mV	
	300 kHz to 1 MHz	15 mV/V + 10 mV	
	(100 to 1 000) V		
	(1 to 40) Hz	400 µV/V + 40 mV	
	40 Hz to 1 kHz	400 µV/V + 20 mV	
	(1 to 20) kHz	600 µV/V + 20 mV	
	(20 to 50) kHz	1.2 mV/V + 20 mV	
	(50 to 100) kHz	3 mV/V + 20 mV	
AC Voltage – Measure	Up to 2.2 mV		Fluke 5790A AC Measurement Standard
	(10 to 20) Hz	0.17 % of reading + 1.3 µV	
	(20 to 40) Hz	0.074 % of reading + 1.3 µV	
	40 Hz to 20 kHz	0.042 % of reading + 1.3 µV	
	(20 to 50) kHz	0.082 % of reading + 2 µV	
	(50 to 100) kHz	0.12 % of reading + 2.5 µV	
	(100 to 300) kHz	0.23 % of reading + 4 µV	
	(300 to 500) kHz	0.26 % of reading + 8 µV	
	500 kHz to 1 MHz	0.5 % of reading + 8 µV	
	(2.2 to 7) mV		
	(10 to 20) Hz	0.085 % of reading + 1.3 µV	
	(20 to 40) Hz	0.037 % of reading + 1.3 µV	
	40 Hz to 20 kHz	0.021 % of reading + 1.3 µV	
	(20 to 50) kHz	0.041 % of reading + 2 µV	
	(50 to 100) kHz	0.061 % of reading + 2.5 µV	
	(100 to 300) kHz	0.12 % of reading + 4 µV	
	(300 to 500) kHz	0.14 % of reading + 8 µV	
	500 kHz to 1 MHz	0.36 % of reading + 8 µV	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure	(7 to 22) mV		Fluke 5790A AC Measurement Standard
	(10 to 20) Hz	0.29 % of reading + 1.3 µV	
	(20 to 40) Hz	0.019 % of reading + 1.3 µV	
	40 Hz to 20 kHz	0.011 % of reading + 1.3 µV	
	(20 to 50) kHz	0.021 % of reading + 2 µV	
	(50 to 100) kHz	0.031 % of reading + 2.5 µV	
	(100 to 300) kHz	0.082 % of reading + 4 µV	
	(300 to 500) kHz	0.1 % of reading + 8 µV	
	500 kHz to 1 MHz	0.26 % of reading + 8 µV	
	(22 to 70) mV		
	(10 to 20) Hz	0.024 % of reading + 1.5 µV	
	(20 to 40) Hz	0.013 % of reading + 1.5 µV	
	40 Hz to 20 kHz	0.006 9 % of reading + 1.5 µV	
	(20 to 50) kHz	0.013 % of reading + 2 µV	
	(50 to 100) kHz	0.026 % of reading + 2.5 µV	
	(100 to 300) kHz	0.053 % of reading + 4 µV	
	(300 to 500) kHz	0.068 % of reading + 80 µV	
	500 kHz to 1 MHz	0.013 % of reading + 8 µV	
	(70 to 220) mV		
	(10 to 20) Hz	0.021 % of reading + 1.5 µV	
	(20 to 40) Hz	0.008 7 % of reading + 1.5 µV	
	40 Hz to 20 kHz	0.004 3 % of reading + 1.5 µV	
	(20 to 50) kHz	0.007 3 % of reading + 2 µV	
	(50 to 100) kHz	0.016 % of reading + 2.5 µV	
	(100 to 300) kHz	0.028 % of reading + 4 µV	
	(300 to 500) kHz	0.04 % of reading + 8 µV	
	500 kHz to 1 MHz	0.12 % of reading + 8 µV	
	(220 to 700) mV		
	(10 to 20) Hz	0.021 % of reading + 1.5 µV	
	(20 to 40) Hz	0.007 8 % of reading + 1.5 µV	
	40 Hz to 20 kHz	0.003 8 % of reading + 1.5 µV	
	(20 to 50) kHz	0.005 6 % of reading + 2 µV	
	(50 to 100) kHz	0.008 4 % of reading + 2.5 µV	
	(100 to 300) kHz	0.021 % of reading + 4 µV	
	(300 to 500) kHz	0.034 % of reading + 8 µV	
	500 kHz to 1 MHz	0.12 % of reading + 8 µV	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure	(0.7 to 2.2) V		Fluke 5790A AC Measurement Standard
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.006 9 % of reading	
	40 Hz to 20 kHz	0.002 9 % of reading	
	(20 to 50) kHz	0.005 2 % of reading	
	(50 to 100) kHz	0.007 6 % of reading	
	(100 to 300) kHz	0.02 % of reading	
	(300 to 500) kHz	0.031 % of reading	
	500 kHz to 1 MHz	0.12 % of reading	
	(2.2 to 7) V		
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.007 % of reading	
	40 Hz to 20 kHz	0.002 9 % of reading	
	(20 to 50) kHz	0.005 3 % of reading	
	(50 to 100) kHz	0.008 8 % of reading	
	(100 to 300) kHz	0.022 % of reading	
	(300 to 500) kHz	0.047 % of reading	
	500 kHz to 1 MHz	0.15 % of reading	
	(7 to 22) V		
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.007 % of reading	
	40 Hz to 20 kHz	0.003 1 % of reading	
	(20 to 50) kHz	0.005 3 % of reading	
	(50 to 100) kHz	0.008 5 % of reading	
	(100 to 300) kHz	0.022 % of reading	
	(300 to 500) kHz	0.047 % of reading	
	500 kHz to 1 MHz	0.015 % of reading	
	(22 to 70) V		
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.007 2 % of reading	
	40 Hz to 20 kHz	0.003 9 % of reading	
	(20 to 50) kHz	0.006 3 % of reading	
	(50 to 100) kHz	0.011 % of reading	
	(100 to 300) kHz	0.022 % of reading	
	(300 to 500) kHz	0.051 % of reading	
	500 kHz to 1 MHz	0.15 % of reading	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure	(70 to 220) V		Fluke 5790A AC Measurement Standard
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.007 2 % of reading	
	40 Hz to 20 kHz	0.003 8 % of reading	
	(20 to 50) kHz	0.007 7 % of reading	
	(50 to 100) kHz	0.011 % of reading	
	(100 to 300) kHz	0.026 % of reading	
	(300 to 500) kHz	0.07 % of reading	
	(220 to 700) V		
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.011 % of reading	
	40 Hz to 20 kHz	0.004 7 % of reading	
	(20 to 50) kHz	0.015 % of reading	
	(50 to 100) kHz	0.085 % of reading	
	(700 to 1 000) V		
	(10 to 20) Hz	0.02 % of reading	
	(20 to 40) Hz	0.011 % of reading	
	40 Hz to 20 kHz	0.004 4 % of reading	
	(20 to 50) kHz	0.015 % of reading	
	(50 to 100) kHz	0.085 % of reading	
AC Voltage – Measure Flatness referenced to 1 kHz	Up to 2.2 mV		Fluke 5790A AC Measurement Standard
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.05 % of reading	
	120 Hz to 1.2 kHz	0.05 % of reading	
	(1.2 to 120) kHz	0.05 % of reading	
	(120 to 500) kHz	0.07 % of reading + 1 µV	
	500 kHz to 1.2 MHz	0.07 % of reading + 1 µV	
	(1.2 to 2) MHz	0.07 % of reading + 1 µV	
	(2 to 10) MHz	0.17 % of reading + 1 µV	
	(10 to 20) MHz	0.3 % of reading + 1 µV	
	(20 to 30) MHz	0.7 % of reading + 2 µV	
	(2.2 to 7) mV		
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.05 % of reading	
	120 Hz to 1.2 kHz	0.05 % of reading	
	(1.2 to 120) kHz	0.05 % of reading	
	(120 to 500) kHz	0.07 % of reading + 1 µV	
	500 kHz to 1.2 MHz	0.07 % of reading + 1 µV	
	(1.2 to 2) MHz	0.07 % of reading + 1 µV	
	(2 to 10) MHz	0.1 % of reading + 1 µV	
	(10 to 20) MHz	0.17 % of reading + 1 µV	
	(20 to 30) MHz	0.37 % of reading + 1 µV	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure Flatness referenced to 1 kHz	(7 to 22) mV		Fluke 5790A AC Measurement Standard
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.05 % of reading	
	120 Hz to 1.2 kHz	0.05 % of reading	
	(1.2 to 120) kHz	0.05 % of reading	
	(120 to 500) kHz	0.07 % of reading	
	500 kHz to 1.2 MHz	0.07 % of reading	
	(1.2 to 2) MHz	0.07 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.17 % of reading	
	(20 to 30) MHz	0.37 % of reading	
	(22 to 70) mV		
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.05 % of reading	
	120 Hz to 1.2 kHz	0.05 % of reading	
	(1.2 to 120) kHz	0.05 % of reading	
	(120 to 500) kHz	0.05 % of reading	
	500 kHz to 1.2 MHz	0.05 % of reading	
	(1.2 to 2) MHz	0.05 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.15 % of reading	
	(20 to 30) MHz	0.35 % of reading	
	(70 to 220) mV		
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.04 % of reading	
	120 Hz to 1.2 kHz	0.04 % of reading	
	(1.2 to 120) kHz	0.04 % of reading	
	(120 to 500) kHz	0.04 % of reading	
	500 kHz to 1.2 MHz	0.05 % of reading	
	(1.2 to 2) MHz	0.05 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.15 % of reading	
	(20 to 30) MHz	0.35 % of reading	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Voltage – Measure Flatness referenced to 1 kHz	(220 to 700) mV		Fluke 5790A AC Measurement Standard
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.03 % of reading	
	120 Hz to 1.2 kHz	0.03 % of reading	
	(1.2 to 120) kHz	0.03 % of reading	
	(120 to 500) kHz	0.03 % of reading	
	500 kHz to 1.2 MHz	0.05 % of reading	
	(1.2 to 2) MHz	0.05 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.15 % of reading	
	(20 to 30) MHz	0.35 % of reading	
	(0.7 to 2.2) V		
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.03 % of reading	
	120 Hz to 1.2 kHz	0.03 % of reading	
	(1.2 to 120) kHz	0.03 % of reading	
	(120 to 500) kHz	0.03 % of reading	
	500 kHz to 1.2 MHz	0.05 % of reading	
	(1.2 to 2) MHz	0.05 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.15 % of reading	
	(20 to 30) MHz	0.35 % of reading	
	(2.2 to 3.5) V		
	(10 Hz to 30) Hz	0.1 % of reading	
	(30 Hz to 120) Hz	0.03 % of reading	
	120 Hz to 1.2 kHz	0.03 % of reading	
	(1.2 to 120) kHz	0.03 % of reading	
	(120 to 500) kHz	0.03 % of reading	
	500 kHz to 1.2 MHz	0.05 % of reading	
	(1.2 to 2) MHz	0.05 % of reading	
	(2 to 10) MHz	0.1 % of reading	
	(10 to 20) MHz	0.15 % of reading	
	(20 to 30) MHz	0.35 % of reading	
AC Current – Source [1]	Up to 220 µA		Fluke 5700A Multifunction Calibrator with 5725A Amplifier
	(10 to 20) Hz	700 µA/A + 25 nA	
	(20 to 40) Hz	350 µA/A + 20 nA	
	40 Hz to 1 kHz	140 µA/A + 16 nA	
	(1 to 5) kHz	600 µA/A + 40 nA	
	(5 to 10) kHz	1.6 mA/A + 80 nA	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source [1]	220 µA to 2.2 mA (10 to 20) Hz (20 to 40) Hz 40Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 22) mA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (22 to 220) mA (10 to 20) Hz (20 to 40) Hz 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz 220 mA to 2.2 A 20 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (2.2 to 11) A 40 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz	 700 µA/A + 40 nA 350 µA/A + 35 nA 140 µA/A + 35 nA 600 µA/A + 400 nA 1.6 mA/A + 800 nA 700 µA/A + 400 nA 350 µA/A + 350 nA 140 µA/A + 350 nA 600 µA/A + 4 µA 1.6 mA/A + 8 µA 700 µA/A + 4 µA 350 µA/A + 3.5 µA 140 µA/A + 3.5 µA 600 µA/A + 40 µA 1.6 mA/A + 80 µA 650 µA/A + 35 µA 750 µA/A + 80 µA 8.5 mA/A + 160 µA 460 µA/A + 170 µA 950 µA/A + 380 µA 3.6 mA/A + 750 µA	Fluke 5700A Multifunction Calibrator with 5725A Amplifier
AC Current – Source [1]	(29 to 330) µA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz (0.33 to 3.3) mA (10 to 20) Hz (20 to 45) Hz 45 Hz to 1 kHz (1 to 5) kHz (5 to 10) kHz (10 to 30) kHz	 0.2 % of reading + 0.1 nA 0.15 % of reading + 0.1 nA 0.13 % of reading + 0.1 nA 0.3 % of reading + 0.15 nA 0.8 % of reading + 0.2 nA 1.6 % of reading + 0.4 nA 0.2 % of reading + 0.15 nA 0.13 % of reading + 0.15 nA 0.1 % of reading + 0.15 nA 0.2 % of reading + 0.2 nA 0.5 % of reading + 0.3 nA 1 % of reading + 0.6 nA	Fluke 5522A Multi-Product Calibrator

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Source [1]	(3.3 to 33) mA		Fluke 5522A Multi-Product Calibrator
	(10 to 20) Hz	0.18 % of reading + 2 nA	
	(20 to 45) Hz	0.09 % of reading + 2 nA	
	45 Hz to 1 kHz	0.04 % of reading + 2 nA	
	(1-5) kHz	0.08 % of reading + 2 nA	
	(5 to 10) kHz	0.2 % of reading + 3 nA	
	(10 to 30) kHz	0.4 % of reading + 4 nA	
	(33 to 330) mA		
	(10 to 20) Hz	0.18 % of reading + 20 nA	
	(20 to 45) Hz	0.09 % of reading + 20 nA	
	45 Hz to 1 kHz	0.04 % of reading + 20 nA	
	(1 to 5) kHz	0.1 % of reading + 50 nA	
	(5 to 10) kHz	0.2 % of reading + 100 nA	
	(10 to 30) kHz	0.4 % of reading + 200 nA	
	330 mA to 1.1 A		
	(10 to 45) Hz	0.18 % of reading + 100 nA	
	45 Hz to 1 kHz	0.05 % of reading + 100 nA	
	(1 to 5) kHz	0.6 % of reading + 1 µA	
	(5 to 10) kHz	2.5 % of reading + 5 µA	
	(3 to 11) A		
	(45 to 100) Hz	0.06 % of reading + 2 µA	
	100 Hz to 1 kHz	0.1 % of reading + 2 µA	
	(1 to 5) kHz	3 % of reading + 2 µA	
	(11 to 20.5) A		
	(45 to 100) Hz	0.12 % of reading + 5 µA	
	100 Hz to 1 kHz	0.15 % of reading + 5 µA	
	(1 to 5) kHz	3 % of reading + 5 µA	
AC Current – Measure [1]	(5 to 100) µA		Hewlett Packard 3458A Digital Multimeter
	(10 to 20) Hz	0.4 % of reading + 30 nA	
	(20 to 45) Hz	0.15 % of reading + 30 nA	
	(45 to 100) Hz	0.06 % of reading + 30 nA	
	(100 Hz to 1 kHz	0.06 % of reading + 30 nA	
	(0.1 to 1) mA		
	(10 to 20) Hz	0.4 % of reading + 200 nA	
	(20 to 45) Hz	0.15 % of reading + 200 nA	
	(45 to 100) Hz	0.06 % of reading + 200 nA	
	100 Hz to 5 kHz	0.03 % of reading + 200 nA	
	(5 to 20) kHz	0.06 % of reading + 200 nA	
	(20 to 50) kHz	0.4 % of reading + 400 nA	
	(50 to 100) kHz	0.55 % of reading + 1.5 µA	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AC Current – Measure [1]	(1 to 10) mA		Hewlett Packard 3458A Digital Multimeter
	(10 to 20) Hz	0.4 % of reading + 2 µA	
	(20 to 45) Hz	0.15 % of reading + 2 µA	
	(45 to 100) Hz	0.06 % of reading + 2 µA	
	100 Hz to 5 kHz	0.03 % of reading + 2 µA	
	(5 to 20) kHz	0.06 % of reading + 2 µA	
	(20 to 50) kHz	0.4 % of reading + 4 µA	
	(50 to 100) kHz	0.55 % of reading + 15 µA	
	(10 to 100) mA		
	(10 to 20) Hz	0.4 % of reading + 20 µA	
	(20 to 45) Hz	0.15 % of reading + 20 µA	
	(45 to 100) Hz	0.06 % of reading + 20 µA	
	100Hz to 5 kHz	0.03 % of reading + 20 µA	
	(5 to 20) kHz	0.06 % of reading + 20 µA	
	(20 to 50) kHz	0.4 % of reading + 40 µA	
	(50 to 100) kHz	0.55 % of reading + 150 µA	
	100 mA to 1 A		
	(10 to 20) Hz	0.4 % of reading + 200 µA	
	(20 to 45) Hz	0.16 % of reading + 200 µA	
	(45 to 100) Hz	0.08 % of reading + 200 µA	
	100 Hz to 5 kHz	0.1 % of reading + 200 µA	
	(5 to 20) kHz	0.3 % of reading + 200 µA	
	(20 to 50) kHz	1 % of reading + 400 µA	
Resistance – Source [1]	0 Ω	40 µΩ	Fluke 5522A Multi-Product Calibrator
	1 Ω	95 µΩ/Ω	
	1.9 Ω	95 µΩ/Ω	
	10 Ω	23 µΩ/Ω	
	19 Ω	23 µΩ/Ω	
	100 Ω	10 µΩ/Ω	
	190 Ω	10 µΩ/Ω	
	1 kΩ	8.5 µΩ/Ω	
	1.9 kΩ	8.5 µΩ/Ω	
	10 kΩ	8.5 µΩ/Ω	
	19 kΩ	8.5 µΩ/Ω	
	100 kΩ	11 µΩ/Ω	
	190 kΩ	11 µΩ/Ω	
	1 MΩ	20 µΩ/Ω	
	1.9 MΩ	21 µΩ/Ω	
	10 MΩ	40 µΩ/Ω	
	19 MΩ	47 µΩ/Ω	
	100 MΩ	100 µΩ/Ω	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source [1]	(0 to 11) Ω (11 to 33) Ω (33 to 110) Ω (110 to 330) Ω (330 to 1 100) Ω (1.1 to 3.3) kΩ (3.3 to 11) kΩ (11 to 33) kΩ (33 to 110) kΩ (110 to 330) kΩ (330 to 1 100) kΩ (1.1 to 3.3) MΩ (3.3 to 11) MΩ (11 to 33) MΩ (33 to 110) MΩ (110 to 330) MΩ (330 to 1 100) MΩ	40 μΩ/Ω + 0.01 Ω 30 μΩ/Ω + 0.015 Ω 28 μΩ/Ω + 0.015 Ω 28 μΩ/Ω + 0.02 Ω 28 μΩ/Ω + 0.02 Ω 28 μΩ/Ω + 0.2 Ω 28 μΩ/Ω + 0.1 Ω 28 μΩ/Ω + 1 Ω 28 μΩ/Ω + 1 Ω 32 μΩ/Ω + 10 Ω 32 μΩ/Ω + 10 Ω 60 μΩ/Ω + 150 Ω 130 μΩ/Ω + 250 Ω 250 μΩ/Ω + 2500 Ω 500 μΩ/Ω + 3 kΩ 3 mΩ/Ω + 100 kΩ 15 mΩ/Ω + 500 kΩ	Fluke 5522A Multi-Product Calibrator
Resistance – Source [1]	10 mΩ 1 Ω 10 kΩ 1 MΩ 2 MΩ 3 MΩ 4 MΩ 5 MΩ 6 MΩ 7 MΩ 8 MΩ 9 MΩ 10 MΩ 12 MΩ 13 MΩ 14 MΩ 15 MΩ 16 MΩ 17 MΩ 18 MΩ 19 MΩ 100 MΩ 200 MΩ 300 MΩ 400 MΩ	0.4 μΩ 0.2 μΩ 4.1 mΩ 10 Ω 41 Ω 61 Ω 81 Ω 100 Ω 120 Ω 140 Ω 160 Ω 180 Ω 200 Ω 2 Ω 3 Ω 4.1 Ω 5.1 Ω 6.1 kΩ 7.1 kΩ 8.1 kΩ 9.1 kΩ 10 kΩ 71 kΩ 110 k Ω 140 k Ω	Fixed Resistors and HRRS Series 100G Ω High Resistance Decade Substituter

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Resistance – Source [1]	500 MΩ 600 MΩ 700 MΩ 800 MΩ 900 MΩ 1.0 GΩ 2.0 GΩ 3.0 GΩ 4.0 GΩ 5.0 GΩ 6.0 GΩ 7.0 GΩ 8.0 GΩ 9.0 GΩ 10.0 GΩ	180 kΩ 210 kΩ 250 kΩ/ Ω 280 kΩ/ Ω 320 kΩ/ Ω 510 kΩ/ Ω 1 MΩ/ Ω 1.5 MΩ/ Ω 2 MΩ/ Ω 2.5 MΩ/ Ω 3 MΩ/ Ω 3.6 MΩ/ Ω 4.1 MΩ/ Ω 4.6 MΩ/ Ω 7.1 MΩ/ Ω	Fixed Resistors and HRRS Series 100G Ω High Resistance Decade Substituter
Resistance – Measure [1]	0 to 10 Ω Up to 100 Ω Up to 1 kΩ Up to 10 kΩ Up to 100 kΩ Up to 1 MΩ Up to 10 MΩ Up to 100 MΩ Up to 1 GΩ	15 µΩ/Ω + 50 µΩ 12 µΩ/Ω + 500 µΩ 10 µΩ/Ω + 500 µΩ 10 µΩ/Ω + 5 mΩ 10 µΩ/Ω + 50 mΩ 15 µΩ/Ω + 2 Ω 50 µΩ/Ω + 100 Ω 500 µΩ/Ω + 1 kΩ 0.5% of reading + 10 kΩ	Hewlett Packard 3458A Digital Multimeter
Capacitance – Source [1]	(220 to 400) pF 0.4 pF to 1.1 nF (1.1 to 3.3) nF (3.3 to 11) nF (11 to 33) nF (33 to 110) nF (110 to 330) nF 330 nF to 1.1 µF (1.1 to 3.3) µF (3.3 to 11) µF	0.5 % of reading + 10 pF 0.5 % of reading + 0.01 nF 0.5 % of reading + 0.01 nF 0.25 % of reading + 0.01 nF 0.25 % of reading + 0.1 nF 0.25 % of reading + 0.1 nF 0.25 % of reading + 0.3 nF 0.25 % of reading + 1 nF 0.25 % of reading + 3 nF 0.25 % of reading + 10 nF	Fluke 5522A Multi-Product Calibrator
Capacitance – Source [1]	(11 to 33) µF (33 to 110) µF (110 to 330) µF 330 µF to 1.1 mF (1.1 to 3.3) mF (3.3 to 11) mF (11 to 33) mF (33 to 110) mF	0.4 % of reading + 30 nF 0.45 % of reading + 100 nF 0.45 % of reading + 300 nF 0.45 % of reading + 1 µF 0.45 % of reading + 3 µF 0.45 % of reading + 10 µF 0.75 % of reading + 30 µF 1.1 % of reading + 100 µF	Fluke 5522A Multi-Product Calibrator

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Inductance – Source [1]	100 µH 100 Hz 200 Hz 400 Hz 1 kHz 10 kHz 1 mH 100 Hz 200 Hz 400 Hz 1 kHz 10 kHz 1 H 100 Hz 200 Hz 400 Hz 1 kHz 10 H 100 Hz 200 Hz 400 Hz 1 kHz	 240µH 240µH 240µH 240µH 240µH 240µH 240µH 240µH 240µH 240µH 270µH 270µH 270µH 270µH 1.2mH 1.2mH 1.2mH 1.2mH	Fixed Inductors
Electrical Simulation of Thermocouple Indicators Source and Measure [1]	Type B (600 to 800) °C (800 to 1 000) °C (1 000 to 1 550) °C (1 550 to 1 820) °C Type C (0 to 150) °C (150 to 650) °C (650 to 1 000) °C (1 000 to 1 800) °C (1 800 to 2 316) °C Type E (-250 to -100) °C (-100 to -25) °C (-25 to +350) °C (350 to 650) °C (650 to 1 000) °C	 0.44 °C 0.34 °C 0.3 °C 0.33 °C 0.3 °C 0.26 °C 0.31 °C 0.5 °C 0.84 °C 0.5 °C 0.16 °C 0.14 °C 0.16 °C 0.21 °C	Fluke 5522A Multi-Product Calibrator

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of Thermocouple Indicators Source and Measure [1]	Type J		Fluke 5522A Multi-Product Calibrator
	(-210 to -100) °C	0.27 °C	
	(-100 to -30) °C	0.16 °C	
	(-30 to +150) °C	0.14 °C	
	(150 to 760) °C	0.17 °C	
	(760 to 1 200) °C	0.23 °C	
	Type K		
	(-200 to -100) °C	0.33 °C	
	(-100 to -25) °C	0.18 °C	
	(-25 to +120) °C	0.16 °C	
	(120 to 1 000) °C	0.26 °C	
	(1 000 to 1 372) °C	0.4 °C	
	Type L		
	(-200 to -100) °C	0.37 °C	
	(-100 to +800) °C	0.26 °C	
	(800 to 900) °C	0.17 °C	
	Type N		
	(-200 to -100) °C	0.4 °C	
	(-100 to -25) °C	0.22 °C	
	(-25 to +120) °C	0.19 °C	
	(120 to 410) °C	0.18 °C	
	(410 to 1 300) °C	0.27 °C	
	Type R		
	(0 to 250) °C	0.57 °C	
	(250 to 400) °C	0.35 °C	
	(400 to 1 000) °C	0.33 °C	
	(1 000 to 1 767) °C	0.4 °C	
	Type S		
	(0 to 250) °C	0.47 °C	
	(250 to 1 000) °C	0.36 °C	
	(1 000 to 1 400) °C	0.37 °C	
	(1 400 to 1 767) °C	0.46 °C	
	Type T		
	(-250 to -150) °C	0.63 °C	
	(-150 to 0) °C	0.24 °C	
	(0 to 120) °C	0.16 °C	
	(120 to 400) °C	0.14 °C	
	Type U		
	(-200 to 0) °C	0.56 °C	
	(0 to 600) °C	0.27 °C	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of RTD Indicating Devices [1]	PT385-100 Ω		Fluke 5522A Multi-Product Calibrator
	(-200 to -80) °C	0.05 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.07 °C	
	(100 to 300) °C	0.09 °C	
	(300 to 400) °C	0.1 °C	
	(400 to 630) °C	0.12 °C	
	(630 to 800) °C	0.23 °C	
	PT3926-100 Ω		
	(-200 to -80) °C	0.05 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.07 °C	
	(100 to 300) °C	0.09 °C	
	(300 to 400) °C	0.1 °C	
	(400 to 630) °C	0.12 °C	
	PT3916-100 Ω		
	(-200 to -190) °C	0.25 °C	
	(-190 to -80) °C	0.04 °C	
	(-80 to 0) °C	0.05 °C	
	(0 to 100) °C	0.06 °C	
	(100 to 260) °C	0.07 °C	
	(260 to 300) °C	0.08 °C	
	(300 to 400) °C	0.09 °C	
	(400 to 600) °C	0.1 °C	
	(600 to 630) °C	0.23 °C	
	PT385-200 Ω		
	(-200 to -80) °C	0.04 °C	
	(-80 to 0) °C	0.04 °C	
	(0 to 100) °C	0.04 °C	
	(100 to 260) °C	0.05 °C	
	(260 to 300) °C	0.12 °C	
	(300 to 400) °C	0.13 °C	
	(400 to 600) °C	0.14 °C	
	(600 to 630) °C	0.16 °C	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Electrical Simulation of RTD Indicating Devices [1]	PT385-500 Ω (-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C PT385-1 000 Ω (-200 to -80) °C (-80 to 0) °C (0 to 100) °C (100 to 260) °C (260 to 300) °C (300 to 400) °C (400 to 600) °C (600 to 630) °C PtNi 385-120 Ω (-80 to 0) °C (0 to 100) °C (100 to 260) °C	 0.04 °C 0.05 °C 0.05 °C 0.06 °C 0.08 °C 0.08 °C 0.09 °C 0.11 °C 0.03 °C 0.03 °C 0.04 °C 0.05 °C 0.06 °C 0.07 °C 0.07 °C 0.23 °C 0.08 °C 0.08 °C 0.14 °C	Fluke 5522A Multi-Product Calibrator
Electrical Simulation of RTD Indicating Devices [1]	Cu 427-10 Ω (-100 to +260) °C	 0.3 °C	Fluke 5522A Multi-Product Calibrator
Oscilloscopes [1] Amplitude	1 mV to 130 VDC (into 1 MΩ) (into 50 Ω)	 0.05 % of reading + 40 µV 0.25 % of reading + 40 µV	Fluke 5522A SC1100 Multi-Product Calibrator
Oscilloscopes [1] Square Wave, 10 Hz to 10 kHz	1 mV to 130 V, 1 MΩ 1 mv to 6.6 V, 50 Ω	0.1 % of reading + 40 µV 0.25 % of reading + 40 µV	
Oscilloscopes [1] Waveform Generator (Square, Sine, Triangle)	1.8 mV to 55 Vpp, 1 MΩ 1.8 mV to 2.5 Vpp, 50 Ω	3 % of reading + 100 µV	
Oscilloscopes [1] Pulse Generator	200 ns to 20 ms	5 % of Pulse Width reading + 2 ns	
Oscilloscopes [1] Frequency Accuracy	0.2 Hz to 1 GHz	2.5 x 10^{-6} of reading	

Electrical – DC/Low Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Oscilloscopes [1] Leveled Sinewave Absolute	50 kHz Reference 50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1 100) MHz	2 % of reading + 300 µV 3.5 % of reading + 300 µV 4 % of reading + 300 µV 6 % of reading + 300 µV 7 % of reading + 300 µV	Fluke 5522A SC1100 Multi-Product Calibrator
Oscilloscopes [1] Leveled Sinewave Flatness (relative to 50 kHz)	50 kHz to 100 MHz (100 to 300) MHz (300 to 600) MHz (600 to 1 100) MHz	1.5 % of reading + 100 µV 2 % of reading + 100 µV 4 % of reading + 100 µV 5 % of reading + 100 µV	
Oscilloscopes [1] Impedance Measurement	40 to 60 Ω 500 kΩ to 1.5 MΩ	0.1 % of reading	
Oscilloscopes [1] Capacitance Measurement	5 pF to 50 pF	5 % of reading + 0.5 pF	

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power – Source (Power Sensor or Thermistor Mount Calibration Factors)	10 µW to 10 mW 0.006 MHz 0.009 MHz (0.02 to 0.09) MHz 0.1 MHz 0.2 MHz (0.3 to 3) MHz 5 MHz (10 to 80) MHz (90 to 150) MHz (200 to 600) MHz 650 MHz 700 MHz to 2 GHz (2.1 to 3.6) GHz (3.7 to 4.6) GHz (4.8 to 10) GHz 10.2 GHz (10.4 to 10.6) GHz (10.8 to 11) GHz (11.2 to 11.8) GHz 12 GHz	0.52 % of reading 0.47 % of reading 0.44 % of reading 0.75 % of reading 0.71 % of reading 0.69 % of reading 0.7 % of reading 0.68 % of reading 0.69 % of reading 0.68 % of reading 0.69 % of reading 0.68 % of reading 0.7 % of reading 0.72 % of reading 0.77 % of reading 0.82 % of reading 0.83 % of reading 0.8 % of reading 0.81 % of reading 0.88 % of reading	Tegam 1830A or Agilent E4418B Power Meter with 2505A RF Power Standard

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
RF Power – Source (Power Sensor or Thermistor Mount Calibration Factors)	10 µW to 10 mW (12.2 to 12.75) GHz (13 to 13.75) GHz (14 to 15) GHz 15.25 GHz (15.5 to 16.5) GHz (16.75 to 18) GHz	 0.89 % of reading 0.87 % of reading 0.88 % of reading 0.89 % of reading 0.87 % of reading 0.88 % of reading	Tegam 1830A or Agilent E4418B Power Meter with 2505A RF Power Standard
RF Power – Source (Power Sensor or Thermistor Mount Calibration Factors)	10 µW to 10 mW 10 MHz 20 MHz 30 MHz (40 to 90) MHz (100 to 250) MHz (300 to 350) MHz (400 to 450) MHz 500 MHz (550 to 650) MHz 700 MHz 750 MHz to 2.4 GHz 2.5 GHz (2.6 to 3) GHz (3.1 to 5.4) GHz (5.6 to 6.4) GHz (6.6 to 9.2) GHz (9.4 to 13.5) GHz (13.75 to 17.5) GHz 17.75 GHz 18 GHz 19 GHz 20 GHz 21 GHz 22 GHz 23 GHz (24 to 26.5) GHz	 1.8 % of reading 1.3 % of reading 1.2 % of reading 1.2 % of reading 1.1 % of reading 1.1 % of reading 1.1 % of reading 1.1 % of reading 1.1 % of reading 1.2 % of reading 1.2 % of reading 1.2 % of reading 1.2 % of reading 1.3 % of reading 1.4 % of reading 1.5 % of reading 1.8 % of reading 2.3 % of reading 2.4 % of reading 2.4 % of reading 2.8 % of reading 2.5 % of reading 2.3 % of reading 2.5 % of reading 3 % of reading 2.9 % of reading	Tegam 1830A or Agilent E4418B Power Meter with F1135B RF Power Standard

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Absolute Power – Source [1,2]	(>+20 to +24) dBm		Absolute Power -- Fluke 96040A Low Phase Noise Reference Source with 50 ohm Leveling Head
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.069 %*X*	
	100 kHz to 10 MHz	0.071 %*X*	
	(10 to 128) MHz	0.071 %*X*	
	(128 to 300) MHz	0.071 %*X*	
	300 MHz to 1.4 GHz	0.087 %*X*	
	(1.4 to 3) GHz	0.28 %*X*	
	(3 to 4) GHz	0.96 %*X*	
	(>+14 to +20) dBm		
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.069 %*X*	
	100 kHz to 10 MHz	0.071 %*X*	
	(10 to 128) MHz	0.071 %*X*	
	(128 to 300) MHz	0.071 %*X*	
	300 MHz to 1.4 GHz	0.087 %*X*	
	(1.4 to 3) GHz	0.28 %*X*	
	(3 to 4) GHz	0.96 %*X*	
	(-17 to + 14) dBm		
	10 Hz to 99.9 kHz	Greater of 0.003 dB or 0.069 %*X*	
	100 kHz	Greater of 0.003 dB or 0.069 %*X*	
	100 kHz to 10 MHz	Greater of 0.003 1 dB or 0.071 %*X*	
	(10 to 128) MHz	Greater of 0.003 1 dB or 0.071 %*X*	
	(128 to 300) MHz	Greater of 0.003 1 dB or 0.071 %*X*	
	300 MHz to 1.4 GHz	Greater of 0.003 8 dB or 0.087 %*X*	
	(1.4 to 3) GHz	Greater of 0.012 dB or 0.28 %*X*	
	(3 to 4) GHz	Greater of 0.042 dB or 0.96 %*X*	
	(-48 to <-17) dBm		
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.069 %*X*	
	100 kHz to 10 MHz	0.071 %*X*	
	(10 to 128) MHz	0.071 %*X*	
	(128 to 300) MHz	0.071 %*X*	
	300 MHz to 1.4 GHz	0.087 %*X*	
	(1.4 to 3) GHz	0.28 %*X*	
	(3 to 4) GHz	0.99 %*X*	

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Absolute Power – Source [1]	(>-74 to <-48) dBm		Absolute Power -- Fluke 96040A Low Phase Noise Reference Source with 50 ohm Leveling Head
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.087 %*X*	
	100 kHz to 10 MHz	0.087 %*X*	
	(10 to 128) MHz	0.074 %*X*	
	(128 to 300) MHz	0.074 %*X*	
	300 MHz to 1.4 GHz	0.13 %*X*	
	(1.4 to 3) GHz	0.3 %*X*	
	(3 to 4) GHz	0.99 %*X*	
	(>-84 to -74) dBm		
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.15 %*X*	
	100 kHz to 10 MHz	0.15 %*X*	
	(10 to 128) MHz	0.074 %*X*	
	(128 to 300) MHz	0.11 %*X*	
	300 MHz to 1.4 GHz	0.15 %*X*	
	(1.4 to 3) GHz	0.37 %*X*	
	(3 to 4) GHz	1 %*X*	
	(>-94 to -84) dBm		
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.15 %*X*	
	100 kHz to 10 MHz	0.15 %*X*	
	(10 to 128) MHz	0.11 %*X*	
	(128 to 300) MHz	0.15 %*X*	
	300 MHz to 1.4 GHz	0.28 %*X*	
	(1.4 to 3) GHz	0.37 %*X*	
	(3 to 4) GHz	0.96 %*X*	
	(-130 to -94) dBm		
	10 Hz to 99.9 kHz	0.069 %*X*	
	100 kHz	0.069 %*X*	
	100 kHz to 10 MHz	0.069 %*X*	
	(10 to 128) MHz	0.2 %*X*	
	(128 to 300) MHz	0.41 %*X*	
	300 MHz to 1.4 GHz	0.41 %*X*	
	(1.4 to 3) GHz	0.48 %*X*	
	(3 to 4) GHz	0.96 %*X*	

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Power Flatness – Source [1]	(>+20 to +24) dBm		Fluke 96040A Low Phase Noise Reference Source with 50 Ω Leveling Head Relative to 100 kHz
	10 Hz to 99.9 kHz	0.003 dB	
	100 kHz to 10 MHz	0.003 1 dB	
	(10 to 128) MHz	0.003 1 dB	
	(128 to 300) MHz	0.003 dB	
	300 MHz to 1.4 GHz	0.003 dB	
	(1.4 to 3) GHz	0.012 dB	
	(3 to 4) GHz	0.042 dB	
	(>+14 to +20) dBm		
	10 Hz to 99.9 kHz	0.003 dB	
	100 kHz to 10 MHz	0.003 1 dB	
	(10 to 128) MHz	0.003 1 dB	
	(128 to 300) MHz	0.003 1 dB	
	300 MHz to 1.4 GHz	0.003 8 dB	
	(1.4 to 3) GHz	0.012 dB	
	(3 to 4) GHz	0.042 dB	
	(-17 to + 14) dBm		
	10 Hz to 99.9 kHz	0.003 dB	
	100 kHz to 10 MHz	0.003 1 dB	
	(10 to 128) MHz	0.003 1 dB	
	(128 to 300) MHz	0.003 1 dB	
	300 MHz to 1.4 GHz	0.003 8 dB	
	(1.4 to 3) GHz	0.012 dB	
	(3 to 4) GHz	0.042 dB	
	(-48 to <-17) dBm		
	10 Hz to 99.9 kHz	0.003 dB	
	100 kHz to 10 MHz	0.003 8 dB	
	(10 to 128) MHz	0.003 2 dB	
	(128 to 300) MHz	0.003 2 dB	
	300 MHz to 1.4 GHz	0.005 6 dB	
	(1.4 to 3) GHz	0.013 dB	
	(3 to 4) GHz	0.043 dB	
	(>-74 to <-48) dBm		
	10 Hz to 99.9 kHz	0.003 dB	
	100 kHz to 10 MHz	0.003 8 dB	
	(10 to 128) MHz	0.003 2 dB	
	(128 to 300) MHz	0.003 2 dB	
	300 MHz to 1.4 GHz	0.005 6 dB	
	(1.4 to 3) GHz	0.013 dB	
	(3 to 4) GHz	0.043 dB	

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Power Flatness – Source [1]	(>-84 to -74) dBm 10 Hz to 99.9 kHz 100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 3) GHz (3 to 4) GHz (>-94 to -84) dBm 10 Hz to 99.9 kHz 100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 3) GHz (3 to 4) GHz (-130 to -94) dBm 10 Hz to 99.9 kHz 100 kHz to 10 MHz (10 to 128) MHz (128 to 300) MHz 300 MHz to 1.4 GHz (1.4 to 3) GHz (3 to 4) GHz	 0.003 dB 0.006 6 dB 0.003 2 dB 0.004 6 dB 0.006 6 dB 0.016 dB 0.044 dB 0.003 dB 0.006 6 dB 0.004 6 dB 0.006 6 dB 0.012 dB 0.016 dB 0.042 dB 0.003 dB 0.003 dB 0.003 dB 0.003 dB 0.003 dB 0.012 dB 0.42 dB	Fluke 96040A Low Phase Noise Reference Source with 50 Ω Leveling Head Relative to 100kHz
Attenuation – Source [1] Relative to +16 dBm output	(0 to 55) dB (55 to 64) dB (64 to 74) dB (74 to 100) dB (100 to 116) dB	0.29 dB 0.035 dB 0.059 dB 0.082 dB 0.18 dB	Fluke 96040A Low Phase Noise Reference Source with 50 Ω Leveling Head Relative to 100 kHz
Attenuation – Source [1] Relative to +10 dBm output	(0 to 49) dB (49 to 59) dB (59 to 69) dB (69 to 94) dB (94 to 110) dB	0.024 dB 0.035 dB 0.059 dB 0.082 dB 0.18 dB	Fluke 96040A Low Phase Noise Reference Source with 50 Ω Leveling Head Relative to 100 kHz

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
AM Depth – Source[1]	99% AM Depth 10 % Depth 20 % Depth 40 % Depth 50 % Depth 60 % Depth 80 % Depth 90 % Depth	 3.7 % Depth 3.7 % Depth 3.8 % Depth 3.8 % Depth 3.7 % Depth 3.8 % Depth 3.7 % Depth	Fluke 96040A Low Phase Noise Reference Source
FM Modulation – Source [1]	50 kHz range, 12.5 MHz Carrier, 100 kHz Deviation Modulation Rate: 20 Hz 400 Hz 1 kHz 10 kHz 50 kHz 75 kHz 100 kHz 125 kHz 150 kHz 200 kHz 50 kHz range, 400 MHz Carrier, 10 kHz Deviation Modulation Rate: 20 Hz 400 Hz 1 kHz 10 kHz 50 kHz 75 kHz 100 kHz 125 kHz 150 kHz 200 kHz	 3.7 % Deviation 3.7 % Deviation 3.7 % Deviation 3.7 % Deviation 4.2 % Deviation 4.2 % Deviation 5.1 % Deviation 5.1 % Deviation 5.1 % Deviation 5.1 % Deviation 3.7 % Deviation 3.7 % Deviation 3.7 % Deviation 3.7 % Deviation 4.2 % Deviation 4.2 % Deviation 5.1 % Deviation 5.1 % Deviation 5.1 % Deviation 5.1 % Deviation	Fluke 96040A Low Phase Noise Reference Source

Electrical – RF/Microwave

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
FM Modulation – Source [1]	50 kHz range, 400 MHz Carrier,500 kHz Deviation Modulation Rate: 20 Hz 400 Hz 1 kHz 10 kHz 5 0kHz 75 kHz 100 kHz 125 kHz 150 kHz 200 kHz	 3.8 % Deviation 3.8 % Deviation 3.8 % Deviation 3.8 % Deviation 4.2 % Deviation 4.2 % Deviation 5.2 % Deviation 5.2 % Deviation 5.2 % Deviation 5.2 % Deviation	FM -- Fluke 96040A Low Phase Noise Reference Source
RF Power – Measure Power Meter Reference at Fixed Frequencies	1 mW, 0 dBm (50, 100, 500) MHz 1 GHz	0.88 % of reading	TEGAM 1830A Power Meter with HP 478A-H75 Thermistor Mount

Mass and Mass Related

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Pressure Source	(0.2 to 25) psi (20 to 1 000) psi	0.005 % of reading + 0.000 85 psi 0.005 % of reading + 0.026 psi	Ruska 2465, Ruska 2465-799 Mass Set, N_2 medium with Pistons 2465-725 2465-729
	(500 to 15 000) psi	0.007 5 % of reading + 0.15 psi	Ruska 2475 with 2475-701 Piston and 2475-940 Mass Set, Helium Medium

Time and Frequency

Parameter/Equipment	Range	Expanded Uncertainty of Measurement (+/-)	Reference Standard, Method, and/or Equipment
Frequency - Source	10 MHz	1 x 10^{-11} Hz/Hz	Xli GPS Receiver

Calibration and Measurement Capability (CMC) is expressed in terms of the measurement parameter, measurement range, expanded uncertainty of measurement and reference standard, method, and/or equipment. The expanded uncertainty of measurement is expressed as the standard uncertainty of the measurement multiplied by a coverage factor of 2 (k=2), corresponding to a confidence level of approximately 95% of reading.

Notes:

1. On-site calibration service is available for this parameter, since on-site conditions are typically more variable than those in the laboratory, larger measurement uncertainties are expected on-site than what is reported on the accredited scope.
2. X = selected output value.
3. This scope is formatted as part of a single document including Certificate of Accreditation No. AC-2986.

Jason Stine, Vice President